

# **EXPANDING PUMICE TECHNOLOGY TO THE PROTECTION OF MISSILE WARHEADS FROM SYMPATHETIC DETONATION\***

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## **ABSTRACT**

Throughout history, developing a method to ensure that explosives are safely stored has perplexed and challenged the military logistian because, when conventional munitions are stored in a centralized location, the possibility of sympathetic detonation exists. This report discusses how a unique admixture, which can provide reliability and safety in storing munitions, was designed and tested.

This admixture is composed of pumice and a material to bond the particles of the pumice. Early tests used plaster of paris as the bonding agent. Although this material was effective, there was concern that it would absorb water. Subsequent tests were conducted using variations of plaster and cement and a two-part epoxy-resin mixture. Of the agents tested, the two-part epoxy resin was the most efficient bonding agent.

A series of tests was conducted on a variety of munitions to evaluate the feasibility of using a pumice-filled container as a barrier to prevent sympathetic detonation and propagation. Most of the large tests were conducted using pumice in its natural form with no bonding material. The munitions were placed inside a container and surrounded by pumice. When a bonding agent was used, the agent served to shape the pumice and hold it in place within the container. Both methods proved effective for stopping sympathetic detonation.

The results of the tests indicated that pumice-filled containers can be used effectively to safely store several specific types of munitions; however, further testing is recommended to establish the minimum container size for maximum effectiveness and to finalize the container's design to ensure safe handling.

## **INTRODUCTION**

The Ordnance Evaluation Section of the Naval Air Warfare Center Weapons Division began working on a method to prevent sympathetic detonation of general purpose bombs in 1986. A survey of various munitions known to sympathetically detonate was conducted. Full-scale propagation tests were then conducted on a variety of bombs and projectiles using pumice technology as a mitigation device. The testing showed promise; however, research emphasis shifted to improving insensitive munitions.

At the same time, a requirement existed for protecting small munitions. The Ordnance Evaluation Section was tasked with demonstrating the ability of pumice to prevent the sympathetic detonation of small munitions or to reduce the maximum credible event to one item.

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Pumice is a foamed volcanic glass—also defined as a white volcanic rock with no odor—that comes from granitic volcanoes. The cells are primarily closed cells, less than 1/2-mm across, and separated by thin membranes of granitic material that forms the matrix of the pumice. Pumice has a specific gravity of 0.95, a density of 0.54 to 1.19 g/cm<sup>3</sup>, and a melting point of 2500°F. The chemical composition of pumice follows.

Chemical Compound	Molecular Formula	Percentage
Silica	SiO <sub>2</sub>	66.6%
Alumina	Al <sub>2</sub> O <sub>3</sub>	18.6%
Ferric Oxide	Fe <sub>2</sub> O <sub>3</sub>	0.9%
Lime	CaO	3.9%
Magnesia	MgO	1.4%
Others		3.7%
Loss on ignition		4.9%

## METHODOLOGY AND RESULTS

### GRENADES

Extensive tests were conducted in 1988 and 1989 to evaluate a prototype container for storing 40-mm, M433 high-explosive, dual-purpose (HEDP) grenades (Reference 1). In 1991, further tests were conducted for storing M433 HEDP grenades, M67 fragmentation hand grenades, and Mk-3A2 concussion grenades (Reference 2). These tests established the proper spacing required between each type of grenade. Two of the tests in the series are discussed in the following paragraphs.

A standard, off-the-shelf, light-steel toolbox was used as a practical container for storing the three types of grenades. Figure 1 shows a typical test setup for fragmentation grenades in the open air and provides the reader with a general idea of what the pumice container looked like.

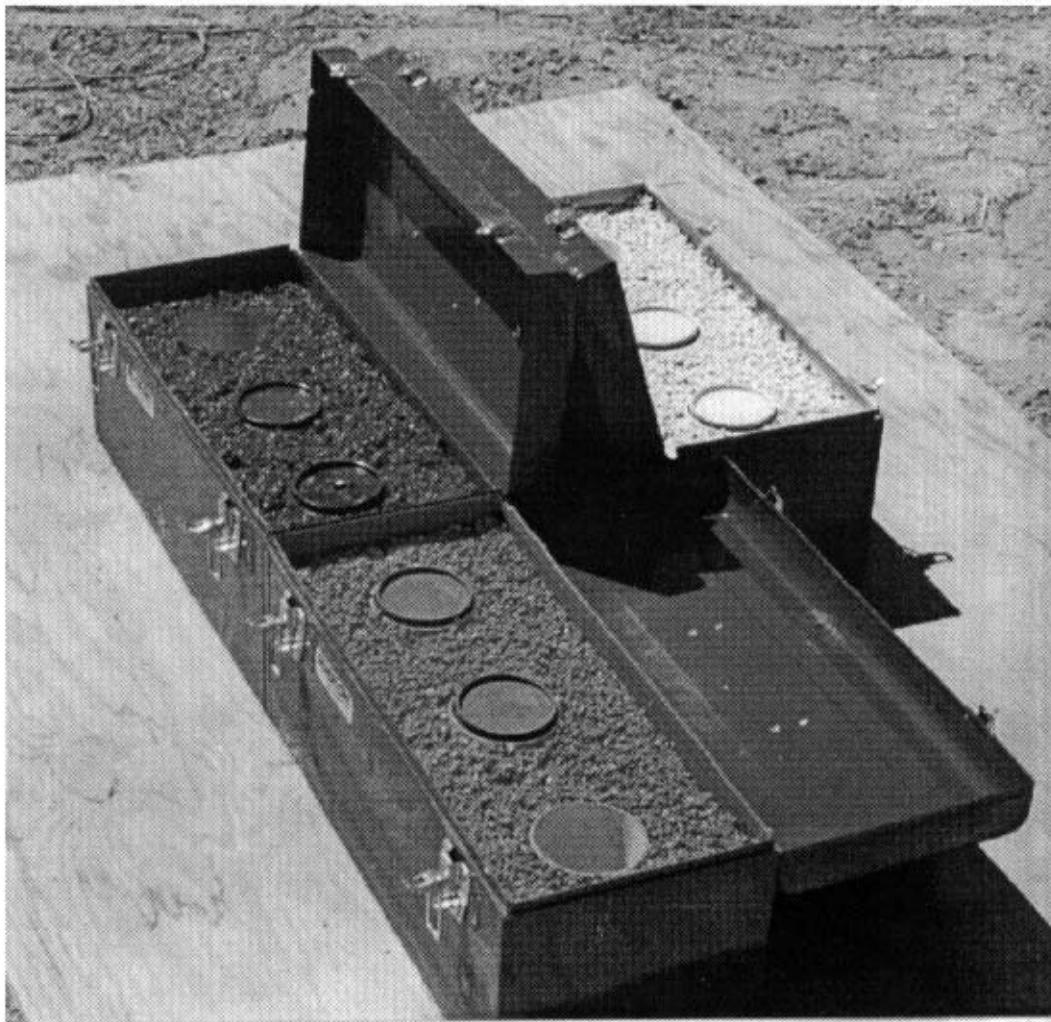
Similar containers were used for all small munitions tests described in this paper. The test was conducted with three containers, each filled with a pumice and epoxy mixture and each having three polyvinyl chloride sleeves, spaced appropriately for the fragmentation grenades. Two grenades were placed in each of the three containers, and each acceptor was assigned a number. The pumice and grenades in the donor/acceptor container were painted red (acceptor No. 1); those in the side-to-side acceptor box, white (Nos. 2 and 3); and those in the end-to-end acceptor box, orange (Nos. 4 and 5).

The donor grenade detonated, blowing the donor/acceptor container apart. The two acceptor containers were also damaged; the acceptor grenades were thrown out of the containers without any reaction. Acceptor No. 1 was found 37.4 feet from ground zero, No. 2 at 77 feet, No. 3 at 41 feet, No. 4 at 78.2 feet, and No. 5 at 51.6 feet.

A second test was conducted, with the same test setup as for the previous test. The results of this second test were similar to those observed in the first test. The donor detonated, blowing the donor/acceptor container apart. The two acceptor containers were also damaged; the acceptor grenades were thrown out of the containers, and the fuze assemblies separated from the grenades without any

reaction. The grenade bodies were not damaged. Acceptor No. 1 was found at 38.4 feet from ground zero, No. 2 at 98.8 feet, No. 3 at 47 feet, No. 4 at 55 feet, and No. 5 at 39.7 feet.

A third series of tests was conducted to verify the capability of pumice to prevent sympathetic detonation in portable magazines. The tests were successful and proved that, with minor modifications to the portable magazine, pumice was effective in stopping sympathetic detonation and reducing the explosives' safety quantity distance (ESQD) arc to zero (Reference 3). The Department of Defense Explosives Safety Board authorized the use of these pumice-filled containers by Special Forces in the Marine Corps to store these specific grenades inside a modified portable magazine.



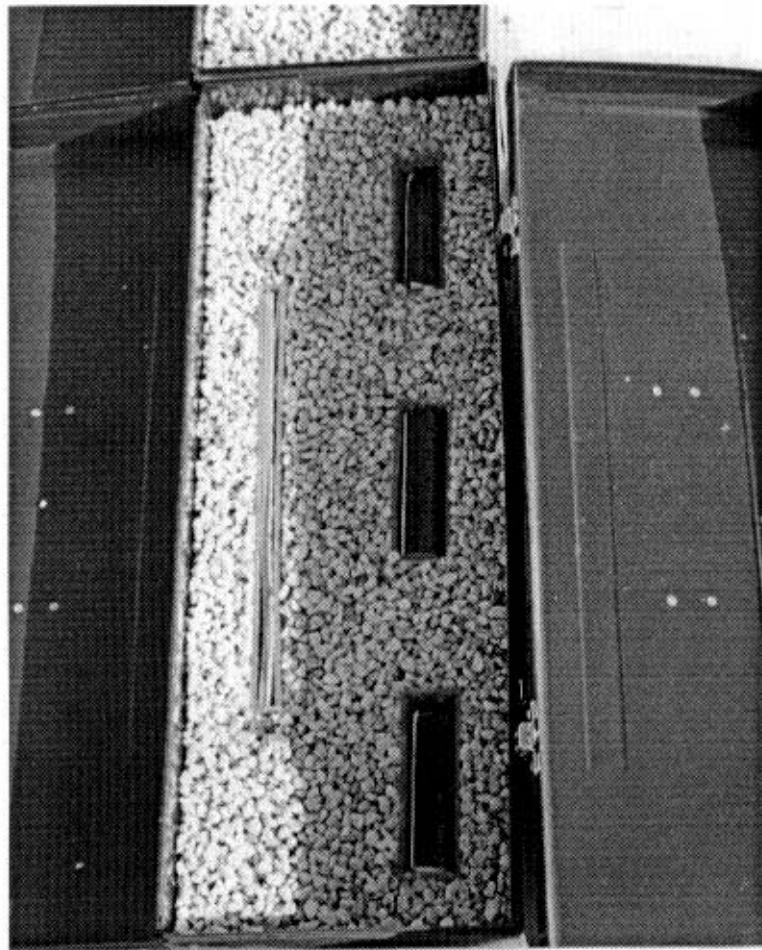
**FIGURE 1. Three Containers of Fragmentation Grenades With a Pumice and Epoxy Mixture.  
The grenades are in their shipping tubes.**

#### **EXPLOSIVE ORDNANCE DISPOSAL QUICK-RESPONSE EXPLOSIVE KITS**

Navy Explosives Ordnance Disposal (EOD) teams required a portable magazine capable of safeguarding a small quantity of Hazard Division (HD) 1.1 demolition explosives for immediate response

with a zero ESQD arc. In 1995, tests were conducted to address this issue (Reference 4). A configuration was developed to store specific demolition explosives in pumice-filled containers inside a modified portable magazine.

Standard light-steel toolboxes were used as containers for all the munitions required by a quick-response EOD Team. Seven different boxes were designed, with appropriate spacing and sleeves to hold the munitions. Figure 2 shows a typical container designed to hold three 1/2-pound blocks of Comp C-4 (the center block was used as the donor for this test) and one sheet of demolition charge.



**FIGURE 2. Pumice-Filled Container with Munitions in Place.**

The seven containers were placed inside a portable magazine; the venting inside the magazine was modified to accommodate the tests. Because HD 1.4 items were required for quick response, these items were placed on a shelf positioned above the pumice containers. The Comp C-4 donor charge was placed inside its container, which was surrounded by the other six containers, and detonated. After detonation, the door of the magazine remained closed and secured with a hardened security lock.

The six containers surrounding the donor container sustained minor damage, but there was no propagation to any other munitions. The shelf remained in place, with most of the HD 1.4 munitions intact. This test was considered a success because the acceptors did not react, and the door of the

magazine did not open. These results are consistent with the results of all other previous tests that used 1/2 pound of explosives as a donor.

## **SHOULDER-LAUNCHED MULTIPURPOSE ATTACK WEAPONS**

A test was conducted to devise a safer method for shipping and storing Shoulder-Launched Multipurpose Attack Weapons. The present container for these weapons consists of a wooden box with two cardboard boxes inside, one on top of the other. Inside each cardboard box is a foam liner molded to hold three weapons. The liner comes in two identical sections, top and bottom. The munitions are aligned to point in the same direction. Each weapon consists of a warhead and a rocket, which are inside a fiberglass tube.

For the test, the molded foam liner was modified by cutting out an 8-inch-long section to line up with the warhead. The section was replaced with a pumice and epoxy mixture, which was molded into a shape similar to the shape of the original cutout, except the bottom had sides high enough to cover the warhead, and the top was a flat piece of the pumice and epoxy mixture. Six live warheads were used, one as a donor and five as acceptors. Empty fiberglass tubes were numbered and placed in the remaining 12 slots of the six complete cardboard boxes. These empty tubes were used to indicate fragment and pressure damage. The cardboard boxes were placed in two stacks. One stack was four boxes high, with the donor in the second box from the bottom and at the side nearest the second stack. The second stack was two boxes high. The donor warhead was near the center, surrounded by live acceptors.

The acceptor closest to the donor received the most damage. This acceptor broke apart, and pieces of the warhead and shaped-charge liner were scattered around the area, but the acceptor did not detonate or burn. The warheads from the other live acceptors remained inside their fiberglass tubes, sustaining only minor damage. The empty fiberglass tubes received little or no damage.

## **155-MM COMP-B-LOADED PROJECTILES**

Three tests were conducted using pumice placed between 155-mm Comp-B-loaded projectiles. The complete details of these tests are reported in Reference 5. The following paragraphs summarize one of the tests.

The test used nine 155-mm Comp-B-loaded projectiles placed—three wide and three long—in a plywood box. The test configuration consisted of nine projectiles standing upright in the box, with 10-inch spacing between each projectile. Dry pumice was placed in the container to cover all but the lifting rings. The center projectile was primed.

The test results indicated that, although the donor detonated and all eight acceptors were broken and scattered around the test arena, the acceptors did not detonate or burn. Sympathetic detonation was prevented by the 10 inches of pumice.

## MK-82 BOMBS

Two field tests—a Nine-Bomb Test and a Seven-Bomb Test—were conducted to further evaluate the pumice concept. A brief summary of these tests is presented in the following paragraphs. Complete details of the tests can be found in Reference 5.

The containers used for both tests were constructed of 1/2-inch plywood. Each container was 74 inches long, 31 inches wide, and 31 inches high (outer dimensions). The footing on each box was 2 inches thick, with two 10.5-inch-wide slots for forklift handling. Before the live Mk-82 bombs were installed, each box was partially filled with a 9-inch layer of dry pumice. The live bombs were then centered in the boxes (5 inches from the inside ends of the box to the nose and tail of the bomb and 9 inches from the sides of the bomb to the inside walls and top and bottom of the box), and dry pumice was added to encase the bomb. Each box was covered with a lid made of 1/2-inch plywood.

For the Nine-Bomb Test, the containers were stacked—three wide and three high—on level ground. The container in the upper-left corner of the stack housed the live donor bomb, which was designated as bomb No. 9. For the Seven-Bomb Test, seven containers were placed side by side in a box-high trench (Figure 3). The container at one end housed the live donor bomb, which was designated as bomb No. 77. Bomb No. 77 was initiated at its base.



FIGURE 3. Seven Mk-82 Bombs in Pumice-Filled Containers Prior to Firing.

During the Nine-Bomb Test, three acceptor bombs next to the donor—beside bomb No. 8, below bomb No. 6, and diagonal to bomb No. 5—were broken, but did not detonate or burn (Figure 4). The other five acceptor bombs were expelled from the boxes and found in undamaged condition as far as 189.4 feet from ground zero. A baseplate from one of the broken bombs was thrown 196.75 feet, the farthest distance away any of the bombs or bomb pieces were scattered.

DONOR NO. 9	ACCEPTOR NO. 8  BROKEN NO REACTION	ACCEPTOR NO. 7  UNDAMAGED
ACCEPTOR NO. 6  BROKEN NO REACTION	ACCEPTOR NO. 5  BROKEN NO REACTION	ACCEPTOR NO. 4  UNDAMAGED
ACCEPTOR NO. 3  UNDAMAGED	ACCEPTOR NO. 2  UNDAMAGED	ACCEPTOR NO. 1  UNDAMAGED

**FIGURE 4. Results of Mk-82 Nine-Bomb Test.**

During the Seven-Bomb Test, the Mk-82 bomb next to the donor—No. 66—was broken, but did not detonate or burn (Figure 5). The main body section of bomb No. 66 was thrown 211.5 feet. Three of the other acceptors were expelled from the trench but were undamaged. The two acceptors farthest away from the donor—Nos. 11 and 22—were found in their original positions, with their containers nearly intact. One fully intact acceptor—No. 55, which was second from the donor—was thrown 180 feet.



**FIGURE 5. Bomb No. 66 After Detonation of No. 77.**

#### **MK-84 BOMBS ON READY AIRCRAFT**

A series of tests was conducted in February and March of 1988 to determine a method to prevent sympathetic detonation of general purpose bombs located on aircraft. Three tests were conducted using an F-16 configuration as the typical aircraft (Figure 6). Summaries of two of these tests are presented in the following paragraphs. Complete details of all three tests can be found in Reference 5.



**FIGURE 6. Concept Drawing of a Typical Aircraft With Pumice Containers Between Mk-84 Bombs.**

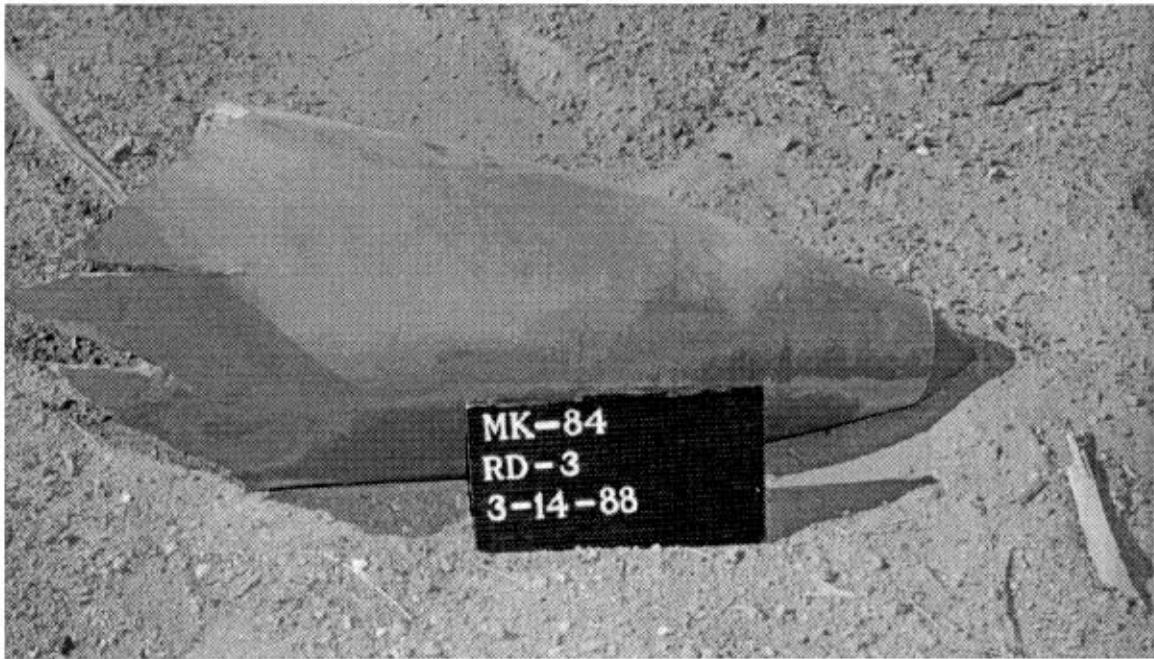
To simulate bombs hanging on an F-16, two Mk-84 bombs were placed parallel, 34 inches apart. The nose of the bomb for the outboard station was offset 33 inches from the nose of the bomb for the inboard station. All measurements were taken from drawings of a loaded F-16. In all tests, the outboard bomb was used as the donor. The outboard bomb was initiated at its nose.

In the first test, two Mk-84 bombs were suspended under a fabricated steel frame to simulate the aircraft wing. The acceptor in this test was an inert concrete-filled bomb to determine whether fragments from the donor impacted the acceptor. A wooden box—112 inches long by 25 inches wide by 25 inches high—was placed between the two bombs. The box was filled with dry pumice material. A 4 1/2-inch space was maintained between the box and edge of each bomb.

For the second test, the ground was raked clean of rocks and debris, then leveled. Two live Mk- 84 bombs were placed on wooden stands. A series of 8-foot by 4-foot by 1/2-inch plywood sheets was placed as base supports for the bomb and box stands. The wooden box was 124 inches long, 25 inches wide, and 37 inches high (outer dimensions).

After the donor was detonated during the first test, the inert bomb was thrown 432 feet to the south of the crater. One side of the inert bomb was deformed from pressure, and the baseplate was separated from the body, but there were no indications of fragment impacts on the bomb. Analysis of high-speed film showed that the pumice deflected much of the blast away from the acceptor.

After the donor was detonated during the second test, the acceptor bomb broke, but from mechanical forces only. The nose piece was located 80 feet southeast of the crater (Figure 7). A large fragment, primarily the strongback section, was located in the crater. The baseplate was located approximately 1173 feet west of the crater. Large and small pieces of explosives were scattered over a large area.



**FIGURE 7. Nose Section of Acceptor Mk-84 Bomb After Detonation in Test.**

Based on high-speed film analysis, the dimensions of the pumice-filled box were increased to be effective in a situation where either the inboard or outboard station bomb was the donor. Further analysis indicated that a taller and longer barrier should be more effective in stopping propagation. Based on the results of these tests, a pumice-filled container is a feasible barrier to prevent sympathetic detonation and propagation.

Further testing is recommended to establish the minimum container size for maximum effectiveness in preventing propagation and to finalize the container's design, not only for effectiveness, but also to ensure safe handling.

#### **SUMMARY AND CONCLUSIONS**

A series of tests was conducted on a variety of munitions to evaluate the feasibility of using a pumice-filled container as a barrier to prevent sympathetic detonation and propagation. Most of the large tests were conducted using pumice in its natural form with no bonding material. The munitions were placed inside a container and surrounded by pumice. When a bonding agent was used, the agent served to shape the pumice and hold it in place within the container. Both methods proved effective for stopping sympathetic detonation.

The results of the tests indicated that pumice-filled containers can be used effectively to safely store several specific types of munitions; however, further testing is recommended to establish the minimum container size for maximum effectiveness and to finalize the container's design to ensure safe handling.

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